CONSERVATION OF RUNOFF FOR CROP AND FORAGE PRODUCTION

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Introduction

As much as half of the scant rainfall on many of the farms and ranches of the Southwestern United States may be lost as runoff under certain conditions. Part of this moisture often can be used profitably to increase the yield of crops and forage. Unless the water is used near its source, much of it is lost to immediate agricultural use, since a large amount of the summer runoff in the Southwest becomes dissipated before it can reach permanent irrigation areas. Even when flows are of sufficient size and duration to empty water into streams feeding irrigation reservoirs, heavy sediment loads often are detrimental to the storage capacity of the reservoirs.

Although some use has been made of such water for many years, improved methods should make possible a wider use (in accordance with state water laws) with considerable benefit to the individual farmer and rancher and to the region as a whole. Several ways of using runoff waters are available, depending on local conditions. Of these, the following are discussed in this bulletin: spreading by total diversion from an arroyo, spreading by partial diversion from an arroyo, spreading by means of structures at the head of gullies, and concentration into hillside crescents. These methods have been tested in connection with soil and water conservation research and demonstration at the Navajo Experiment Station in northwestern New Mexico.

Total Diversion From An Arroyo

By total diversion is meant the spreading of all the runoff water which comes down the arroyo as contrasted with partial diversion, or the use of selected flows or of parts of each flow. The use of all the runoff has proved effective in increasing forage production on properly selected areas (Figures 1 to 4).

In this type of water spreading, a dam is constructed across an arroyo at a suitable place to divert the runoff to the selected area; and, in sites where the water has a tendency to return to the arroyo soon after leaving the spillway, the dam should be extended as a dike to carry it away from the arroyo.

Some care is necessary in selecting a site upon which to spread water. The character of the spreading area, that of the contributing drainage area, and the quantity of water and sediment are all of importance. The amount of runoff that can be expected will vary with the size of the contributing drainage area and the annual precipitation; the higher the precipitation on the area above the dam, the smaller this area may be. In any case, the spreading site must receive at least one good flooding a year. With an annual precipitation of 12 to 15 inches and with a good summer rainfall, this has been found to require a drainage area of at least 2,000 acres.

The land from which the runoff comes should have at least a fair plant cover, since water from badlands and other bare slopes carries excessive amounts of sediment and will damage too much of the spreading area. When the water carries even moderately large amounts of sediment, the usual condition in the Southwest, this must be borne in mind when an area is selected.

The area should be sufficiently large to accommodate the sediment in the upper portion and leave enough land that receives little or no deposit to produce forage. The deposit is deep near the point of diversion and thins out to a negligible amount farther down. The extent of this heavy deposit depends on the shape and slope of the area and upon the quantity of water diverted. Thus it is less on a broad, nearly level plain than it is on a narrow, relatively steep area receiving a comparable amount of water and sediment.

At this Station, on a diversion area that is three miles long and that is narrow and relatively steep just below the spillway, the deposit has been heavy for about 0.6 of a mile. In the upper half of this area of heavy deposit, damage to the grasses has been severe; but in the lower half, increased growth of the grasses that are left has offset the decrease in density. During nine years of diversion, the deposit has reached an average depth of about two feet near the spillway; but at less than a mile below the spillway, it is negligible, and the forage production has greatly increased. In a single year, enough hay was cut from a part of this area to pay for the cost of the dam.

Figure 1. This earthen diversion dam diverts all the runoff from 2,500 acres to a spreading area of approximately 600 acres.

Figure 2. Runoff passing through the spillway of a diversion dam onto a spreading area.

Figure 3. Diverted runoff spreading on range land.

Figure 4. A hay field that resulted from spreading runoff.

Western wheatgrass has been found able to withstand large amounts of sediment and to increase on the areas of heavy deposit. Figure 5 shows this grass growing where there has been a deposit of five feet in as many years. Every effort should be made to get western wheatgrass established where the sediment is heavy. This may be done by sowing seeds directly on the area or by placing them in the spillway and allowing the water to carry them over the area.

Figure 5. Western wheatgrass growing on four to five feet of sediment just below a diversion dam. White cloth in right foreground is tied to the top wire of a four-wire fence, which is buried in the deposit.

Some maintenance work on the spreading areas is desirable. Where water flows back into the arroyo, dikes should be built to stop it, thus preventing headcutting and waste of water. At places where erosion starts, wire-bound rock sausage dams should be buried or spreader fences of brush or heavy net wire should be erected. Also, spreader fences should be placed where sediment deposit or some natural obstruction narrows the flooded area; and sausages or spreader fences are necessary in stretches where the fall exceeds six to nine inches to 100 feet.

If these precautions are taken as soon as they show signs of being necessary, the cost of maintenance may be held to a minimum.

Total diversion may be used for growing corn and oats, but, where there is much sediment in the water, beans do not do well. Records taken from fields of corn in the vicinity of this Station show an average acreage yield of 30 bushels on flooded areas as compared with 14 bushels on comparable dry farming areas. For crop lands, partial diversion, described in the next section, is to be preferred.

Partial Diversion From An Arroyo

Although soils studies have shown that the only measurable effect of the large quantities of sediment brought onto the land by total diversion during nine years has been a change in soil texture, the raising of the soil surface may present obstacles to the continued efficient use of water on crop lands. The answer lies in the use of relatively clearer water. This end may be achieved (1) by desilting, (2) by "skimming off" the upper portion of the flows and allowing the lower portion with the greater part of the sediment to pass on down the arroyo, or (3) by selecting the flows that carry relatively little sediment and allowing the others to pass. The last of these alternatives is probably the most economical, since the first requires a desilting basin, which must be cleaned periodically, or an area of sufficient size to accommodate the sediment during the period the field is to be used; and the second requires a more elaborate and expensive installation.

The structures for obtaining a selection of flows may be simple, inexpensive, and temporary (Figure 6); or elaborate and permanent (Figure 7). Figure 8 shows an intermediate type, which, although permanent, is relatively inexpensive and simple. The installation shown in Figure 7 may be used for selecting flows or for taking off the relatively clearer water and allowing the bulk of the sediment to escape. If anything other than a small, simple structure is contemplated, it is advisable to consult a Soil Conservation Service engineer.

If the field is at a distance from the intake, thus necessitating a ditch, the ditch should be constructed on such a grade that it will neither cut nor fill. Such a ditch at this Station was constructed with a fall of six inches in every 100 feet and, under local conditions, functioned well over a period of several years (Figure 9).

Figure 6. Here is the simplest and most inexpensive type of diversion. The camera case is sitting on a remnant of the diversion dam, which is reconstructed across the arroyo when it is desired to divert a flow through the canal shown in the upper right corner of the picture.

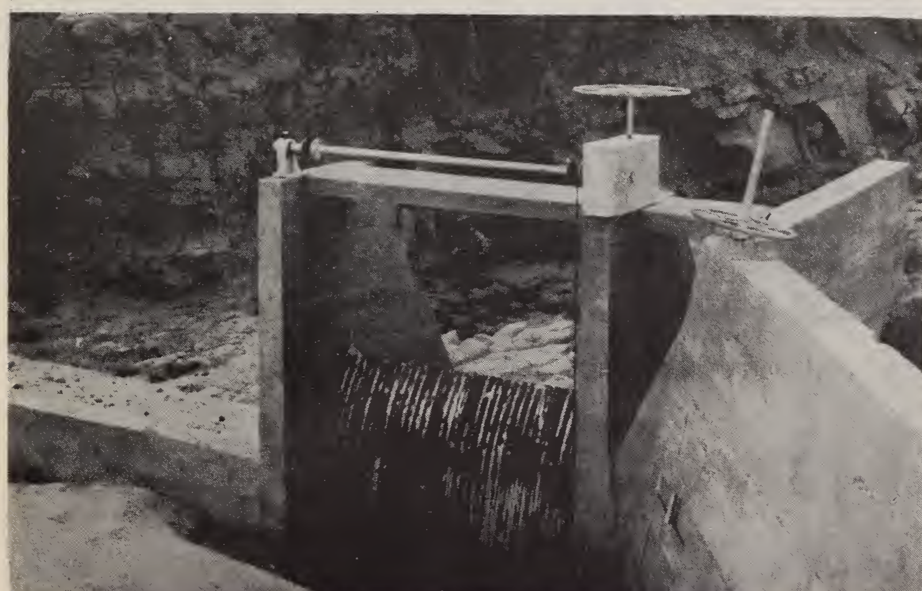

Figure 7. This is an elaborate structure for the partial diversion of water from an arroyo. Water is diverted through the small gate at the right, and excess water carrying the heavier sediment escapes through the large gate. This structure, built by the U. S. Indian Service, serves an area of more than 500 acres.

Figure 8. This is an intermediate type of partial diversion. This diversion, although simple and relatively inexpensive, has the advantage of being permanent. The head wall and gauge are not essential to this type of installation, which was built for another purpose.

Figure 9. This partial-diversion ditch irrigates farm land some distance below the intake.

In selecting flows, the needs of the crop and the amount of sediment in the water are the deciding factors. Thus, in a period of drought when the crop needs moisture

Figure 10. These samples show changes in the sediment load of a single flow in an arroyo. No. 4, from highest stage of flow, 2:30 p.m., 26 per cent sediment. No. 5, from same flow at 2:45 p.m., 14 per cent sediment. No. 6, from same flow at 3:10 p.m., 13 per cent sediment. No. 7, from same flow at 4:35 p.m., 7 per cent sediment. Sediment in sample No. 4 is much too high. In cases of drought, samples Nos. 5 and 6 might be used. Sample No. 7 is within the desirable range. Percentages are by weight. (Note: This picture illustrates the changes in sediment load which may occur during a single flow, and does not illustrate the silt test described in the text.)

badly, water will be used which otherwise would be by-passed because of its sediment content. To determine whether or not the sediment load is so great as to make using the water undesirable, a sample may be taken in a quart fruit jar. To this sample a tablespoonful of air-slaked lime should be added. The jar should be well shaken and allowed to stand undisturbed for 10 minutes. If, at the end of this period, the sediment has settled to a depth of two inches or less, the water may be used safely. If a pint milk bottle is used instead of a quart fruit jar, the depth of the sediment should be one inch

or less. In either case, the container must be full for reliable results. Samples taken at this Station have shown that flows which in their highest stages carry undesirable amounts of sediment may later become clear enough to use (Figure 10). Therefore, samples should be taken at later intervals if the first indicates too great an amount of sediment.

In sections where there is runoff from melting snow in the late winter or early spring, this water is usually relatively clear; and all such water should be used, since often sufficient moisture from this source may be stored in the soil to produce at least a partial crop. Fall flows, also, should be used on corn fields even though the crop is mature or has been harvested, so that the soil will enter the winter with as much moisture as possible.

TABLE 1. Comparison of acreage yields from comparable areas under dry farming, total diversion, and selection of flows.

Farming method	Crop				Total accumulation of sediment
	Corn (bushels)	Beans (pounds)	Oat hay (tons)	Oat grain (bushels)	
Dry	17	577	.7	13	
Total diversion	40	324	1.4	28	20 inches
Selection of flows	52	1380	1.8	32	4 inches

Table 1 gives five-year averages of acreage yields of corn, beans, and oats on comparable areas of dry land, that irrigated with every flow, and that irrigated with selected flows. It is apparent that selection of flows not only held down the deposit of sediment but produced the best yields in all three crops. Over the five-year period one acre of land watered with selected flows has produced on the average as much corn as three acres of dry land and as much of the other crops as two and a half acres. During this time the lowest yield of corn on the irrigated land was 34 bushels to the acre, while the lowest on the dry land was three bushels. Figures 11 to 14 show corn produced in plot studies comparing water spreading with dry farming.

This form of diversion has been successfully used on areas up to 500 acres in size.

Figure 11. Corn shown growing under dry farming conditions in a study plot in 1940.

Figure 12. Corn growing under partial diversion in a study plot in 1940.

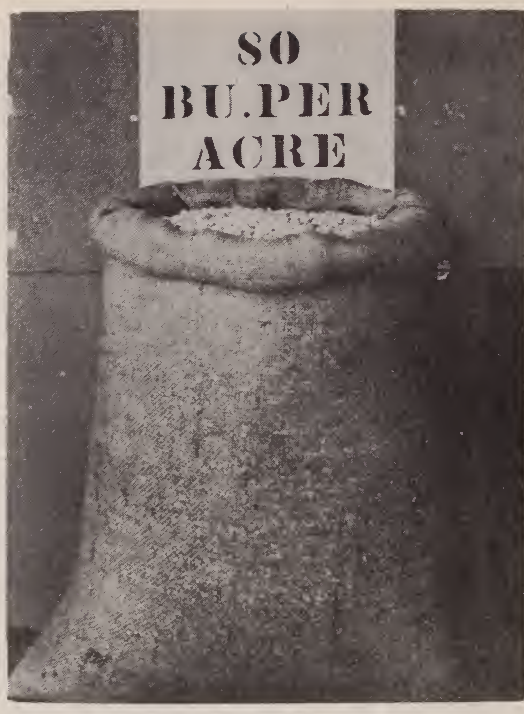

Figure 13. Acreage yield from corn grown under partial diversion in 1940.

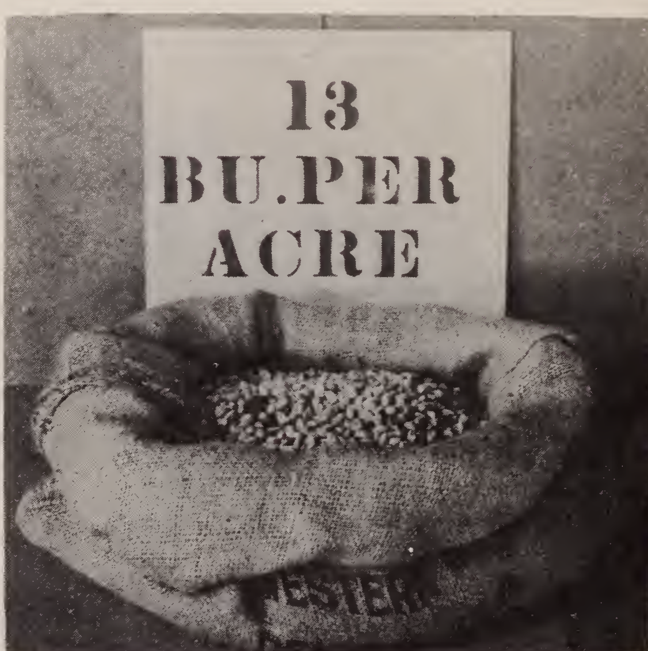

Figure 14. Acreage yield from corn grown under dry farming conditions in 1940.

Gully Control Structures

In regions where the precipitation is insufficient for the efficient practice of dry-farming methods, areas that receive a concentration of water may be used advantageously for the production of feed or garden crops. Such areas are likely to become focal points for severe erosion, and control structures often are necessary. It has been found at this Station that erosion-control structures, such as dikes to prevent headcutting of gullies, may be made to provide bits of arable land to produce corn, beans, oats, or alfalfa. This was demonstrated behind headcutting dikes built on an arroyo that drained an

Figure 15. This is one of a series of small fields behind headcutting dikes.

area of about 500 acres (Figure 15). These dikes were built along a level contour line, and the land behind them was leveled. Some of these sites were as large as half an acre, and the combined total area was three and a half acres.

When the runoff water came down the valley, it was impounded and spread over the leveled area, which acted as a shallow reservoir with an approximate depth of six inches. When the water had filled the reservoirs, the

excess flowed to the next area through a stone spillway. If the amount of runoff was sufficient to overflow the last cultivated area, it escaped onto range land; thus none of it was wasted, and erosion was effectively controlled.

Usually these areas received from one to three floodings a year. One flooding in the late fall or the following spring, however, was found to be sufficient to grow a subsequent crop. In this region an area of 500 acres will not give sufficient runoff every year to produce a crop, but, since the primary purpose of the structures is that of erosion control, anything produced behind them provides that much added income.

TABLE 2. Comparative yields from flood and dry farming.

Crop	Year	Total annual precipitation (inches)	Unit of Yield	Dry Farming	Farming behind Structures
Corn	1936	10.3	bushels	8.6	23.0
	1937	10.1	"	8.0	14.5
Beans	1936	10.3	pounds	0.0	1046.0
	1937	10.1	"	0.0	683.2
Oats	1936	10.3	bushels	0.0	19.4
	1937	10.1	"	0.0	6.4
Alfalfa	1936	10.3	tons	No Stand	Stand
	1937	10.1	"	" "	0.6

Crop yields from these areas, as compared with yields of fields receiving only rainfall, are given in Table 2. It may be seen from this table that, as an average for the two-year period, the acreage yield of corn from these areas was 2.3 times that from fields receiving only precipitation; and that the yields of the other crops were fair to good as compared with no yield on the dry land. From this it is apparent that, in such instances, structures of the sort described may be made to control erosion and at the same time to pay for themselves in a relatively short period.

Hillside Crescents

The use of runoff before it has become concentrated in gullies is an effective means of controlling local erosion and conserving water. This may be accomplished by the use of ordinary contour terraces or of hillside crescent dikes arranged as shown in the diagram (Figure 16). The usual purpose of contour terraces is to hold

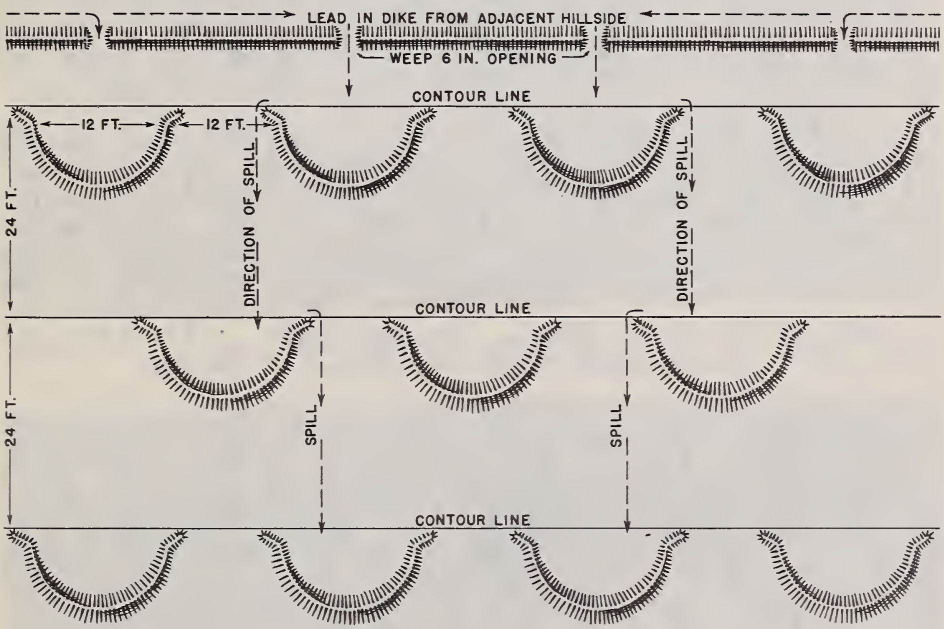

Figure 16. Diagramatic ground-plan for hillside crescents.

precipitation as nearly as possible where it falls, and crescent dikes may be used for the same purpose where land is rough and does not lend itself to the construction of ordinary terraces. These dikes may be used effectively for concentrating sheet runoff from small areas to provide the additional moisture required by fruit or shade trees around the farmstead or ranch house. They have been used for both purposes since their introduction at this Station in 1934.

As may be seen from the diagram, the ground plan for laying out the crescents is simple. The task of building the dikes is relatively easy, since the work usually must be done by hand. They do not have to withstand

heavy onslaughts of running water, and therefore may be built in spare time without danger of loss. In laying out the tract, a contour line is first surveyed near the top of the slope for the first line of crescents. If it is impracticable to start near the top of the slope, a drainage dike should be constructed along this first contour line to protect the crescents below. In either case, contour lines are surveyed at intervals of about 20 feet down the slope to the foot of the hill, or as far down the slope as it is desirable to put crescents. The distance between these contour lines will vary with the fall of the slope and the amount of precipitation expected. The crescents should be spaced far enough apart to insure each receiving a total of 30 to 35 inches of water including the precipitation which actually falls into it.

When the contour lines have been surveyed, points are established along them at intervals of not less than 25 feet. These points will serve as centers for describing the crescents, which are semicircular. As is shown in Figure 16, the points on the second contour line should fall midway between those of the first line; those on the third line, directly below those on the first; and so on, to the last line. Thus, the crescents will alternate with those of the line above and the line below.

Figure 17. Hillside crescents holding water and snow.

Figure 18. A drain ditch which concentrates water from adjacent slopes and spills it into the crescents through weeps.

Figure 19. A close-up view of weep showing simple design. If stone is not available, posts and burlap may be used as shown in Figure 18.

From each established point a semicircle is described on the ground on the down-hill side of the contour line. In describing this semicircle, a six-foot piece of string is used, giving a crescent 12 feet across on the open side.

A dike is built on the semicircle (Figure 17), using soil from within. The crest of this dike must be at least six inches higher in the center than it is on the ends in order that the water may spill around the ends of the dike when the crescent is full. The ends of the semicircle may be flared to facilitate this spilling of the water to the next lower row of crescents. Owing to the alternate arrangement of the crescents, water spills from one into the two below. Thus erosion and loss of water are reduced to a minimum.

If it appears that more water is desirable than can be furnished by the area in which the crescents lie, it often may be diverted to the area from adjacent slopes. A drain ditch collects the runoff from these slopes and spills it into the top row of crescents through small weeps (Figures 18 and 19). If there is a slope above the crescents that has been cut off by a contour dike as mentioned above, such weeps may be placed in this dike to allow part of the runoff from this slope to escape into the crescents.

Precautions and Recommendations

The foregoing describes and illustrates soil and water conservation measures which pay for themselves directly either by markedly increasing yields of forage and crops or by making possible the raising of plants that could not be grown otherwise. These measures are not fool-proof. Also, water rights should always be looked into, and maintenance of structures is imperative. If the following points are considered, no real difficulties should arise.

Water spreading by total diversion.

1. The contributing drainage area must be of sufficient size to insure at least one good flooding a year.

2. The slopes of the contributing drainage area must have at least a fair plant cover and should not be of the nature of badlands.

3. The spreading area must be flat to gently sloping.

4. The spreading area must be of sufficient size to accommodate a large quantity of sediment in the upper 1/6 to 1/4, and the area of heavy deposit should be completely protected from grazing livestock.

5. Western wheatgrass or some other sediment-resisting grass, such as vine mesquite, should be established on the area of heavy deposit.

6. This method of using runoff is recommended for range lands.

Water spreading by partial diversion.

1. The contributing drainage area should furnish at least one good application early in the growing season.

2. The sediment content of the water, as determined by the described rapid test, should be relatively low.

3. Water storage in the soil, as obtained by late fall and early spring applications, is recommended.

4. This method of using runoff is recommended for crop production, or for areas of range land too small to accommodate the expected amounts of water or sediment.

Water spreading by gully headcutting dikes.

1. Dikes should be extended on the contour line farther than necessary for gully-head protection.

2. Spillways should be of such a nature as to avoid erosion.

3. This method is recommended for small garden and crop areas.

Water concentration in hillside crescents.

1. Crescents should be on the contour line.

2. Crescents should not be too close together.

3. Crescent dikes must be higher in the center than at the ends in order to insure proper spilling.

4. Crescents must be sufficiently large to allow for adequate water storage.

5. This method is recommended for growing shade and fruit trees.

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